Title	Comparing Low-Cost Sensors with Ground-Based and Airborne In-Situ and Column Observations of NO_2 and HCHO during the FRAPPE Field Campaign in Colorado, USA

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Abstract	Even in the presence of more reliable air quality tools, low-cost sensors have the benefit of recording data on highly localized spatial and temporal scales, allowing for multiple measurements within a single satellite pixel and on pixel boundaries. However, they are less accurate than their regulatory-grade counterparts, requiring regular co-locations with accepted instruments to ensure their validity. Thus, the addition of low-cost sensors to a field campaign – where reference-grade air quality instruments are abundant – not only provides ample opportunities for low-cost sensor co-location and calibration, but also allows the low-cost instruments to be used for sub-pixel validation, covering more surface area than the regulatory instruments alone with a network of sensors. During the summer of 2014, our low-cost sensor network was deployed during the Front Range Air Pollution and Photochemistry Éxperiment (FRAPPÉ) campaign conducted to sample the composition of air at and above ground level in northeastern Colorado, USA. Airborne campaign measurements included slant column optical observations of formaldehyde (HCHO), nitrogen dioxide (NO2), and ozone (O3). Myriad additional in-situ instruments described chemical composition up to approximately 5 km above surface level. Ground-based instrumentation included both stationary and mobile regulatory-grade instruments, which were used for sensor calibration. Machine learning techniques such as artificial neural networks (ANNs) were used to match the low-cost signals to that of the reference-grade instruments. Here, we compare calibrated low-cost sensor data collected at ground level in a variety of locations along Colorado's Front Range to various data sources from the FRAPPÉ campaign to better understand how well airborne and regulatory ground-based measurements can be extrapolated to other locations. Further, as the slant column measurements act as satellite simulators, we explore how low-cost instruments can be used for satellite validation purposes. The low-cost sensor platform included a suite of gas-phase sensors, notably NO2 and two generalized volatile organic compound (VOC) sensors, which were leveraged together to quantify speciated hydrocarbons such as formaldehyde. These key pollutants were chosen for their impacts on human health and climate change, as well as their inclusion on the TEMPO satellite launching this year. Comparisons among these different data types also have important implications in data fusion.

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